IEEE P802.15 Working Group for Wireless Personal Area Networks

Dialog with FCC

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Outline

- Background
- Coexistence Performance Evaluation of WPANs and WLANs in the 2.4 GHz band.
  - Simulation models (MAC, PHY, Channel)
  - Results
- Coexistence Mechanisms
- Current Status
- Questions to the FCC

Industry Related Coexistence Activities

- The IEEE 802.15 Coexistence Task Group 2 is formed (January 2000) to develop:
  - a model of coexistence between WPAN and WLAN devices,
  - an IEEE recommended practice, and
  - possibly modifications to IEEE 802.11 and 802.15 specifications that allow the proper operation of these protocols in a cooperating way.

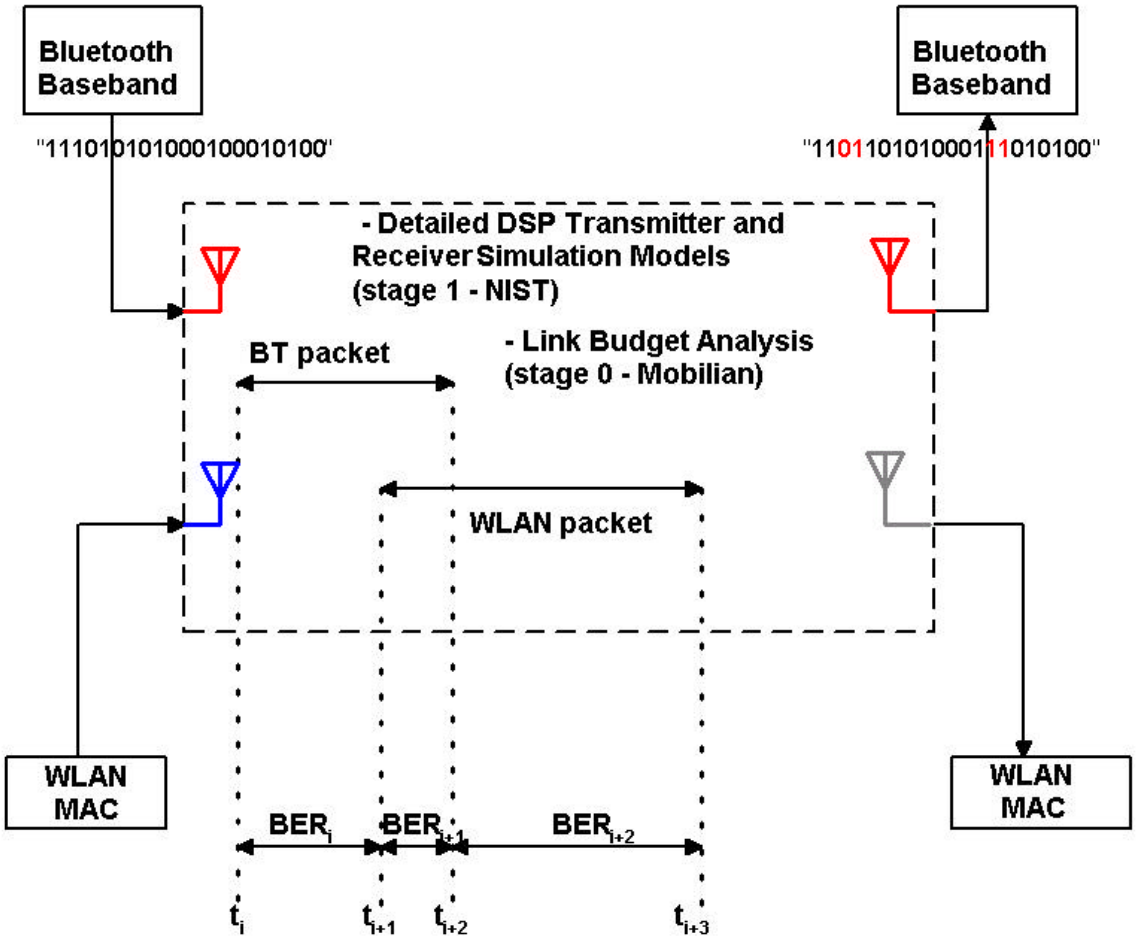
Industry Related Coexistence Activities

- The Bluetooth SIG is also working on the coexistence issue
  - Performance evaluation (simulation, experimental data)
  - Liaison activity with IEEE 802.15 TG2 and publication of results
  - Recently established Bluetooth SIG Radio 1.X Improvement Working Group to implement coexistence-related changes to the standard.

Task Group 2 Focus

- Performance evaluation and modeling of WPAN and WLAN interference
  - conduct experiments
  - develop simulation models for the Bluetooth, WLAN MAC, PHY and RF channel.
  - collect simulation, analytical and experimental data
- Establish coexistence mechanisms
  - classify coexistence mechanisms into 2 categories
    - collaborative
    - non-collaborative
  - evaluate the proposed the coexistence mechanisms

System Simulation Modeling



Parameters IN
Main Packet: Type, Power, Frequency, distance(tx,rx)
Interfererence Packet: Type, Power, Frequency, distance(tx,rx), Time Offset

Channel Modeling

- Additive White Gaussian Noise, multipath fading
- Path loss model

$$Lp = \begin{cases} 32.45 + 20\log(f.d) & d < 8m \\ 58.3 + 33\log(d/8) & otherwise \end{cases}$$

- Received power and SIR depend on topology and device parameters:

$$P_R = P_T - L_P$$

$$SIR = P_R - P_I$$

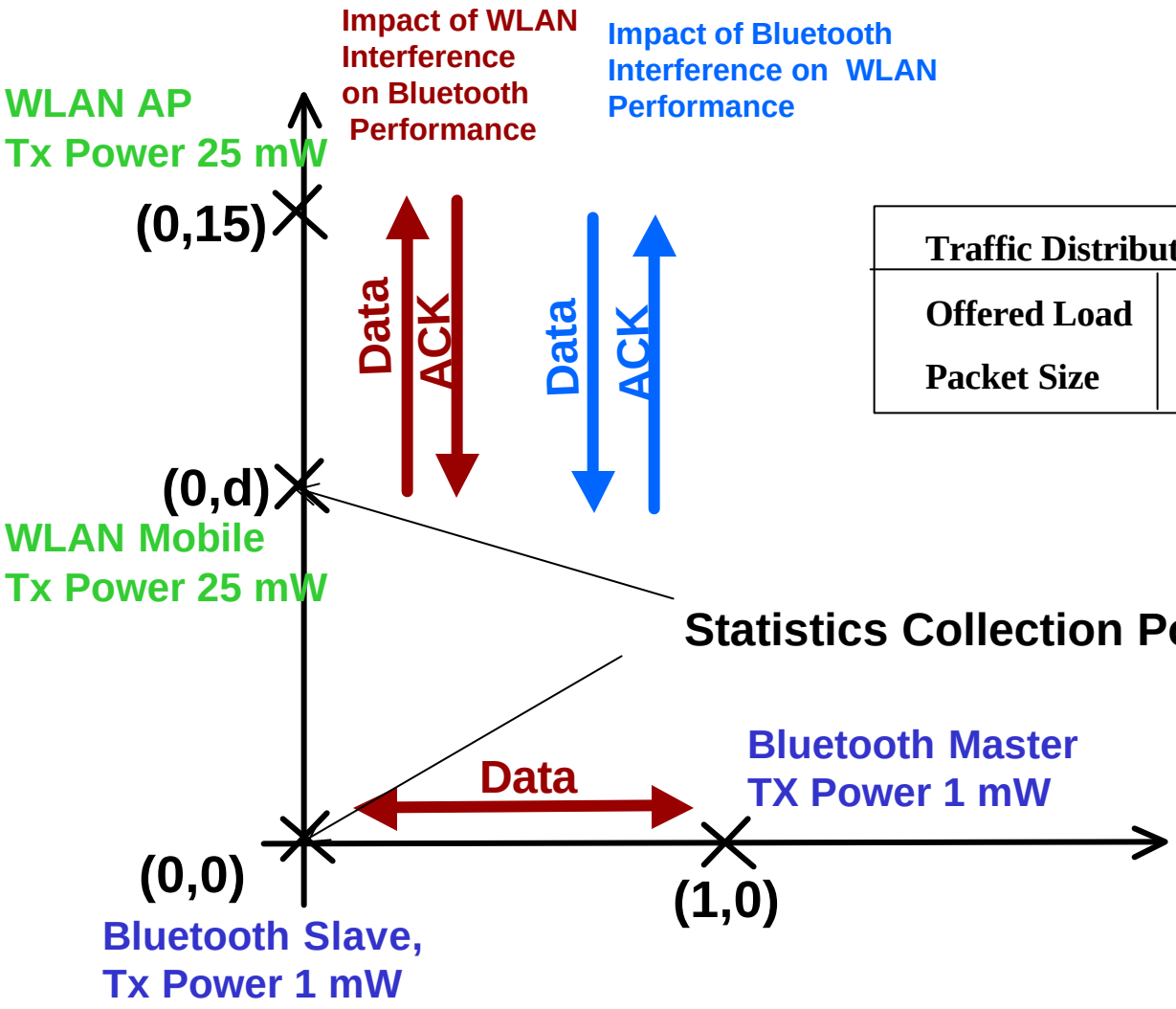
PHY Modeling

- DSP based implementation of transceivers
- Design using typical parameters (goal is to remain non-implementation specific)
- Bluetooth
  - Non-coherent Limiter Discriminator receiver,
  - Viterbi receiver with channel estimation and equalization
- IEEE 802.11
  - Direct Sequence Spread Spectrum (1,2 Mbits/s)
  - Complementary Code Keying (5.5, 11 Mbits/s)
  - Frequency Hopping (1,2 Mbits/s)

MAC Modeling

- MAC behavioral implementation for Bluetooth and IEEE 802.11 (connection mode)
- Frequency hopping
- Error detection and correction
  - Different error correction schemes applied to packet segments (Bluetooth)
  - Frame Check Sequence (FCS) (802.11)
- Performance statistics collection
  - Access delay
  - packet loss
  - residual error
  - throughput

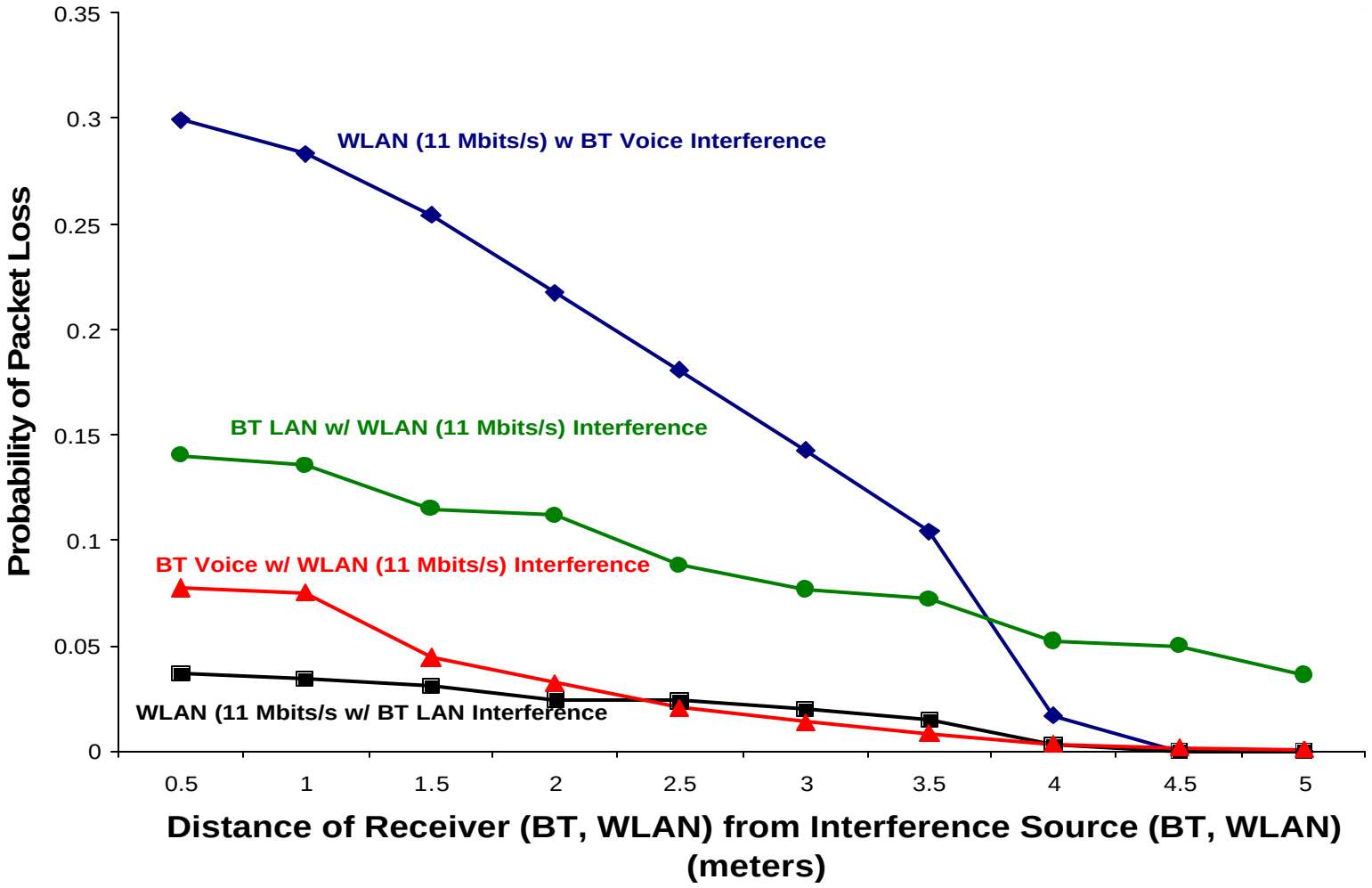
Simulation Scenario



Traffic Distribution for WLAN and BT (LAN)	
Offered Load	30 % Of Channel Capacity
Packet Size	Geometric Distr. Mean 368 bytes

IEEE 802.5-TG2/ 00388r0

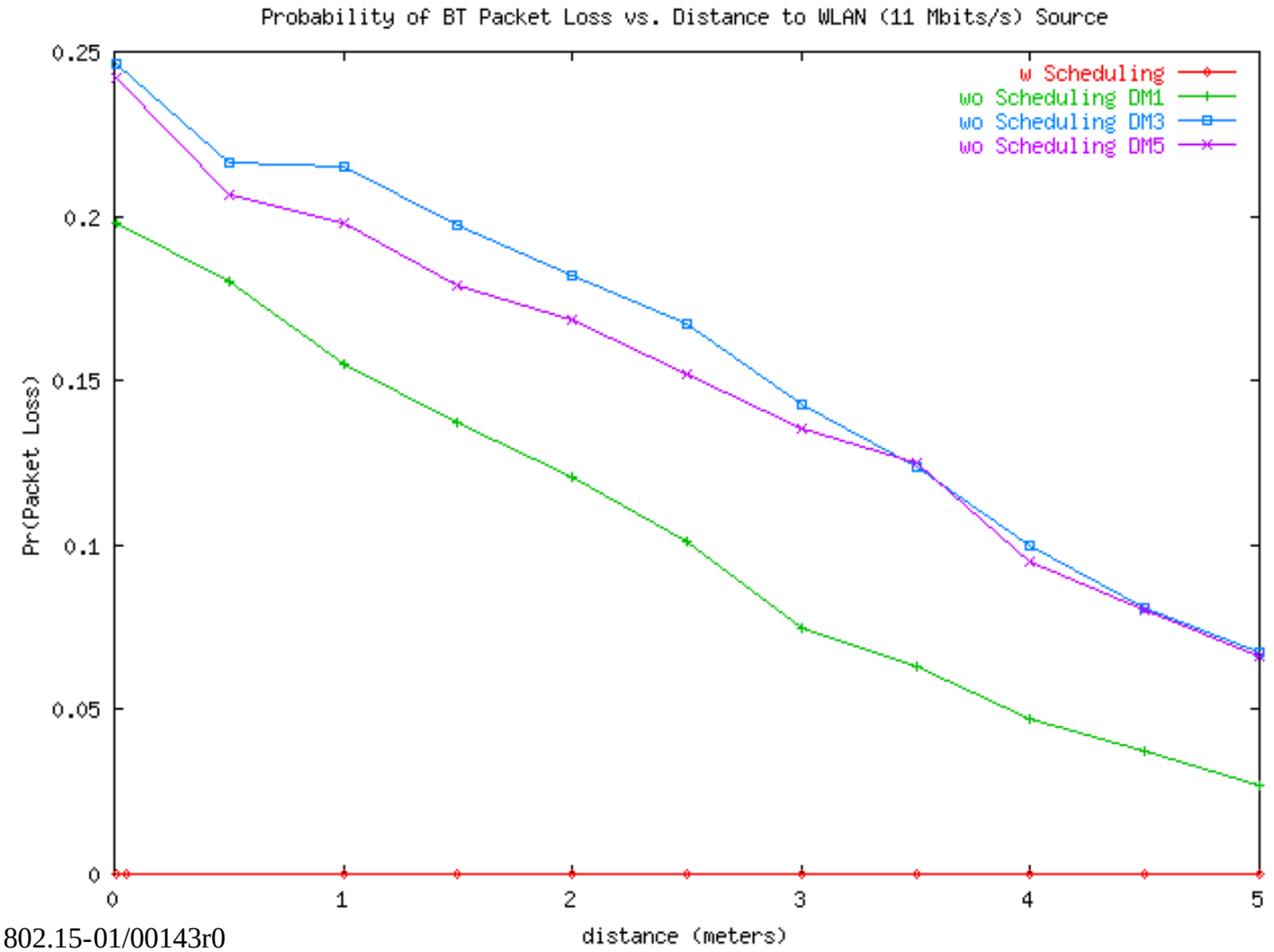
Impact of Interference on Packet Loss



Coexistence Mechanisms

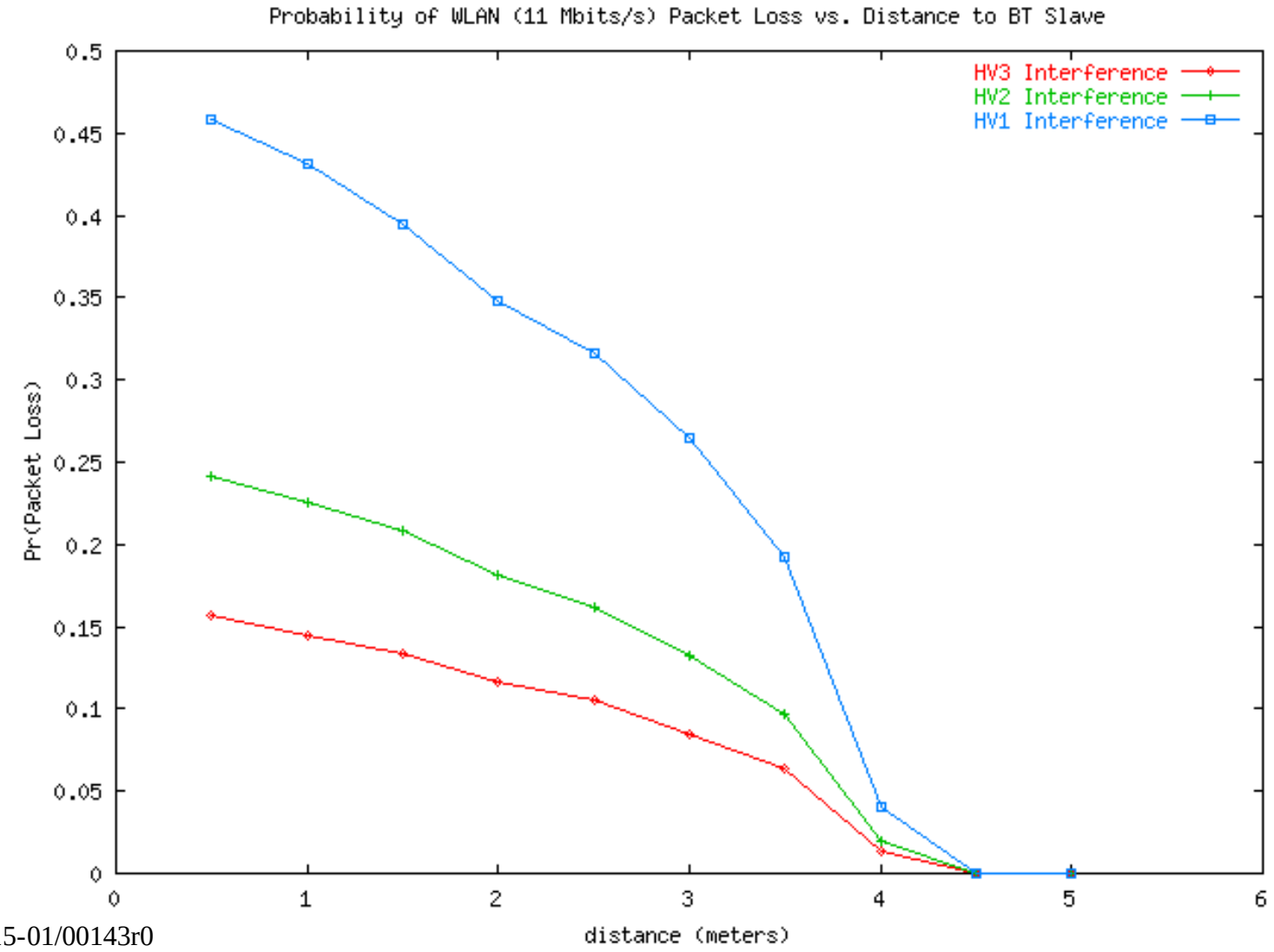
- Collaborative:
  - TDMA solution for scheduling Bluetooth and 802.11 packets on the same device.
  - Frequency nulling
- Non-collaborative:
  - Adaptive frequency hopping
  - Varying packet size, data rates, encapsulation
  - MAC scheduling
  - Transmit power control

Effect of Scheduling on BT



IEEE 802.15-01/00143r0

HV3 is ”Friendlier” to WLAN



IEEE 802.15-01/00143r0

Current Status

- Modeling:
  - Completed performance evaluation of Bluetooth and 802.11 for 1 and 11 Mbits/s
  - Performance analysis and validation of simulation results.
- Coexistence mechanisms:
  - submission of coexistence proposals
  - evaluation of techniques submitted to TG2
  - voting on coexistence mechanisms.

Current FCC rules

- FCC,"Title 47, Code for Federal Regulations," Part 15, October 1998 state
  1) "Frequency hopping systems operating in the 2400-2483 MHz (..) shall use 75 hopping frequencies. (..) The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 30 second period."
  2) "The incorporation of intelligence within a frequency hopping spread spectrum system that permits the system to recognize other users within the spectrum band so that it individually and independently chooses and adapts its hopsets to avoid hopping on occupied channels is permitted. The coordination of frequency hopping systems in any other manner for the express purpose of avoiding simultaneous occupancy of individual hopping frequencies by multiple transmitters is not permitted."

Bluetooth Current Specifications

- Bluetooth uses 79 pseudo-random hopping frequency pattern
- Therefore the average time of occupancy on any one frequency is bounded by:

30/79 = 0.37 seconds.

Questions to the FCC (1)

- BT Scheduling:
  - Bluetooth device “learns” about the environment so that it decides not to transmit in “bad” channels.
  - Since we are not changing the hopping pattern the average time of occupancy on any single frequency is still less than 0.4 seconds.
  - Is this allowed under current FCC rules?
  - Since the rules specify that 75 channels need to be used within 30 seconds, then during a 30 second period, bad frequencies can probed at least once by a POLL/NULL message exchange between the master/slave.
  - Is this allowed under current FCC rules?

Questions to the FCC (2)

- Adaptive Frequency Hopping:
  - Change of Bluetooth hopping pattern so that it avoids channels that are occupied by other devices such as WLAN (802.11b Direct Sequence)
  - Reduced hopping set to n frequency channels (n < 75) and transmitted power can be reduced accordingly.
  - In Europe and Japan as few as 20 hopping channels may be used allowing for flexibility.
  - Change is adaptive so that device has to “learn” about the environment.
  - Change will allow for increased efficiency and reduced spectral usage.
  - Is this allowed under current rules?

Questions to the FCC (3)

- Adaptive Frequency Hopping:
  - If it is not allowed, how do we go about changing the rules?
  - Is the public benefit clear to you?
  - What is the timeline associated with changing the rules?